Space Weather Technical Forecast

Issued on Thursday, 20 July 2023 at 13:18 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: R1/R2 Likely throughout. Chance of G1/G2 to end UTC week. Reducing Chance of further S1 periods.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been Moderate in the past 24 hours, with GOES16 registering a peak M3.8 at 19/1725UTC from now-departed Ex-AR3363. The departure of this sunspot group heralded a change in character of the observed X-ray trace at the satellite, with previously frequent low-level C-class flares interspersed with isolated moderate activity - instead falling to a stable flat trace near C1 by the end of the reporting period.

There were up to eight sunspot regions on the disc in the period - well-scattered across much of the facing side in regions of starkly-opposing magnetic polarity across the solar 'tropics'. A new high latitude sunspot became visible near S45E75, however this has yet to be numbered. The disc otherwise contains numerous large and nominally complex regions, with perhaps the most notable being AR3373 near centre-disc, with slight proliferation in its leading spots and the presence of a Mt Wilson delta. In addition to this, there was slight proliferation of small trailing spots in AR3376 and AR3378, otherwise remaining spots were relatively stable.

Figure 0: SIDC ROB-derived detection of X-ray flare locations for C-class and above in the past 72 hours – note the clustering near the southwestern limb from now Ex-AR3363. This departure is the rationale for the near-term slight reduction in the risk of further flares.

A CME was observed leaving the west limb of the Sun in association with the M3.8 flare - this has

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been modelled, and although the latest MOSWOC Enlil model does have a minority of ensemble members with narrow glancing incidence in the UTC day of 23 July, the perturbed CME parameters needed for these hits are considered improbable, and this feature is instead thought a likely miss to no effect. No other Earth-directed CMEs were observed in the available imagery.

Solar Wind / Geomagnetic Activity: Solar wind parameters, as measured by ACE and DSCOVR at L1, showed a stable slow wind regime. The solar wind speed showed a very slight slowing tendency, falling from near 425km/s to nearer 375. The solar wind density was near background levels in single figures ppcc, while the IMF was steady at or below 6nT with a north-south component of -3/+5nT. The phi angle was negative (towards the Sun). The net effect of the above solar wind measures was for provisionally Quiet Kp indices throughout, peaking at Kp 1+ in the 03-06 and 06-09UTC intervals.

Energetic Particles / Solar Radiation: The high energy (greater than 2MeV) electron flux remained largely at Moderate levels, with a peak of 1140pfu observed at 19/1845UTC. The 24-hour integrated fluence responded with a corresponding increase, but remained well below the Active (1e8 integrated pfu) threshold: a fluence of 5.47e7 pfu was recorded at 20/0001UTC.

The high energy proton flux (greater than 10MeV), as observed by GOES16, showed a continuing gradual relaxation in the period, falling through the 10pfu S1 threshold in moving from 36pfu to 7 in the current period, having earlier peaked at 620pfu in the immediate aftermath of the causative M5.7 flare that occurred 18/0000UTC.

Four-Day Space Weather Forecast Summary

Solar Activity: Activity carries a chance of returning to Moderate over the following days, with a Chance of isolated M-class flares and a Slight Chance of an X-class flare. The character of the observed X-ray trace is currently changed as Ex-AR3363 has left the disc (becoming quieter), and a tentatively identified new lower level of risk may now again rise day-on-day with progressive far-side arrivals in the four-day period.

Solar Wind / Geomagnetic Activity: The geomagnetic forecast is relatively low confidence to end the current week especially. This is both for the presence of up to two possibly Earth-directed CMEs - one of which is now overdue - but also because of the tenuous but probably inconsequential coronal hole arrangement on the disc. There remains a Chance of G1/G2 to end the UTC working week, although the chances of Moderate geomagnetic activity are now considered slightly lower for the overdue first CME. Thoughts on the second transient remain unchanged, and this is overlaid over uncertain but likely minor coronal hole influence.

Geomagnetic activity should become more reliably Quiet by the end of the coming UTC weekend, barring new CME-producing events.

Energetic Particles / Solar Radiation: The high energy electron flux (greater than 2MeV), appears to have reached a steady state and no significant changes are expected until after any geomagnetic activity from either of the outstanding CMEs materialises. There is a gradually increasing Chance of Active 24-hour integrated fluence as a result.

The high energy (greater than 10MeV) proton flux has recently crossed the S1 threshold on a downward trajectory, having earlier reached a peak of S2 and 620pfu at 18/0620UTC. The chances of further such occurrences are held higher than the raw disc probabilities - both for the presence of Ex-AR3363 over the limb, but also because of the high starting point for near-Earth proton flux, meaning relatively little further addition is needed for S1 at least.

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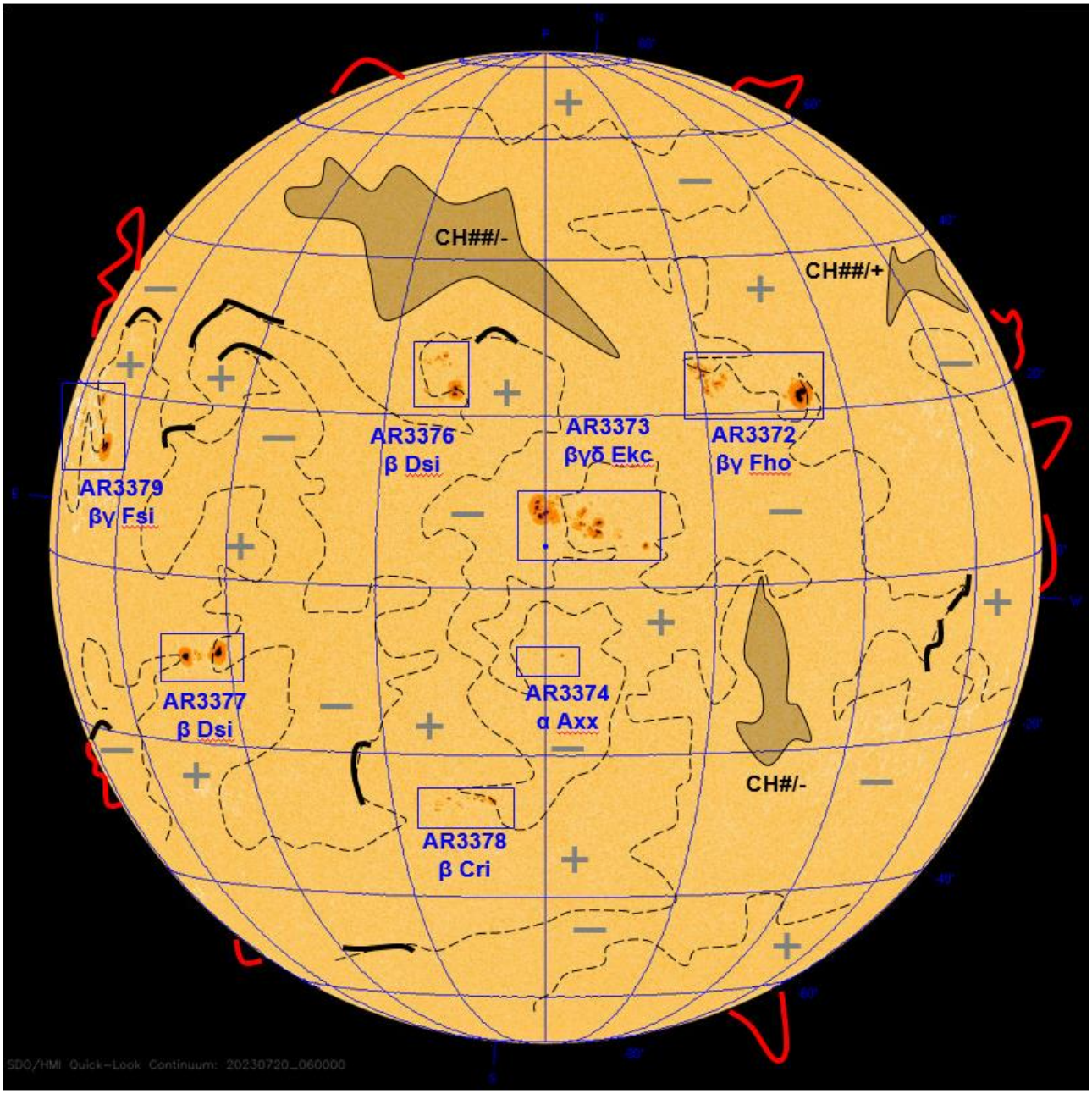
Figure 1. Solar Analysis Valid 20/0600UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

Two potentially Earth-directed CMEs feature in this forecast. The first one originates from the M5.7 flare that occurred around 18/0000UTC. While the bulk of the ejecta is expected to pass the south and west of Earth, it may give an imminent glancing blow in the remainder of current UTC day, although there are as yet no signs of this occurring (e.g. from ACE EPAM LEMS).

The second CME of interest was observed leaving the Sun from the northeast limb around the same time as the M2.1 flare that occurred around 18/2000UTC. While the bulk of the ejecta is believed to head east of the Sun-Earth line, it may give a glancing blow on Day 2 (Friday 21 July). Satellite imagery was very scant during the eruption, giving low confidence in this analysis. The coronal hole-based forecast also carries relatively high uncertainty in details for the period, although this is not expected to be unduly impactful given their tenuous appearance on the disc and the probable dominance of any CMEs.

Quiet geomagnetic activity is Likely to become Active over the remainder of day 1 (Thursday 20 July), albeit with a now reduced chance of G1/G2 (Minor/Moderate) storms, especially the latter for the necessarily slower CME speed or more glancing incidence involved. These intervals may continue into day 2 (Friday 21 July), both in the tail of the earlier CME, possibly bolstered by the second transient. Activity should then return to mainly Quiet with a chance of Unsettled intervals from later day 3 (Saturday 22 July), as residual CME effects wane.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	30	30	10	1
Strong	G3	No	1	10	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

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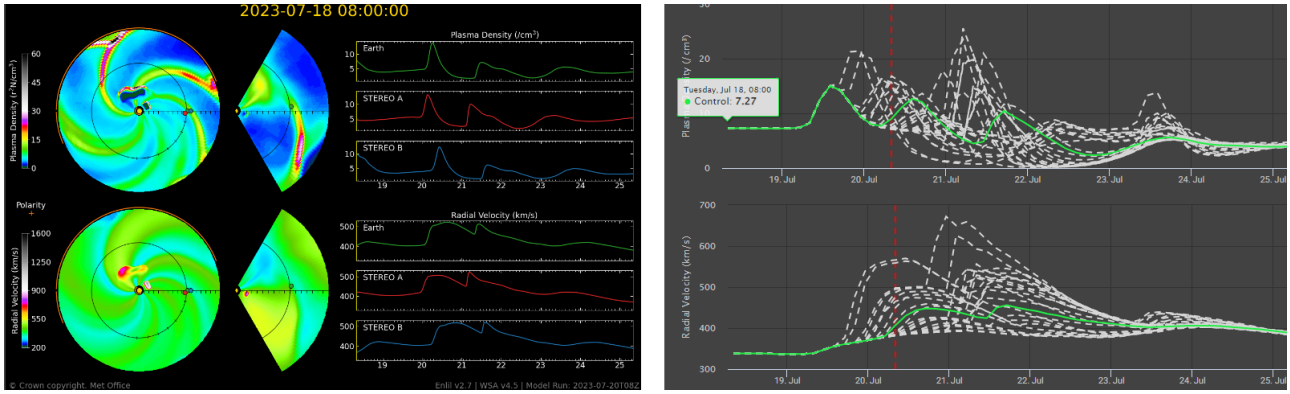
Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
18/0145	Asymmetric full	M5.7 from AR3363	SW quadrant	1630km/s	Imminent	Overdue since 20/0600UTC, bulk or entirety passing S and E of Earth.
18/2300	Asymmetric	M2.1 from AR3376	NE quadrant	1200km/s	21/0900UTC +/-6 hours	Bulk passing W of Earth.

Figure 2: Latest MOSWOC Enlil forecast, showing up to three clusters of marginal passes by CMEs: respectively the 18 July M5.7 CME (now overdue); the 18 July M2.1 CME and now also the 19 July M3.8, which shows as a marginal glance in a handful of members, but these third CME perturbations are considered improbable on closer investigation, and the deterministic miss is preferred.



Radio Blackouts - X-Ray Flares:

Solar activity has remained Moderate in the period, however then sunspot region that has been chiefly responsible for this, Ex-AR3363, has now both crossed the western solar horizon and rotated away sufficiently that further Earth-visible X-ray activity is unlikely. The now quiescent background X-ray trace at GOES16 is perhaps illustrative of the degree to which AR3363 was responsible for the lion's share of recent activity.

Nominally, the current disc still retains a daily Likelihood of further M-class flares, however this has yet to be borne out in appreciable activity. This is despite the presence of up to six Zurich D-, E- and F-groups, including AR3373, which has a developing Mt Wilson delta spot in its leading portion. Another noteworthy arrangement is the polarity in AR3376, which has a negative polarity leader (in the northern solar hemisphere), and an east-west aligned magnetic neutral line, the latter meaning shear instability is more likely in this group. AR3379 too, is a group with a very large span and plage, and the current appearance of well-spaced relatively symmetric umbrae is likely to show further infill with small spots as the viewing angle improves.

The balance of front-sided regions is now more likely to increase than decrease in the forecast period, with far-sided soundings showing near-continuous returns in both hemispheres, meanwhile all with no departures from the front-side. Already, there are signs that there may be an arriving (very) high latitude bipolar spot group near S45E75.

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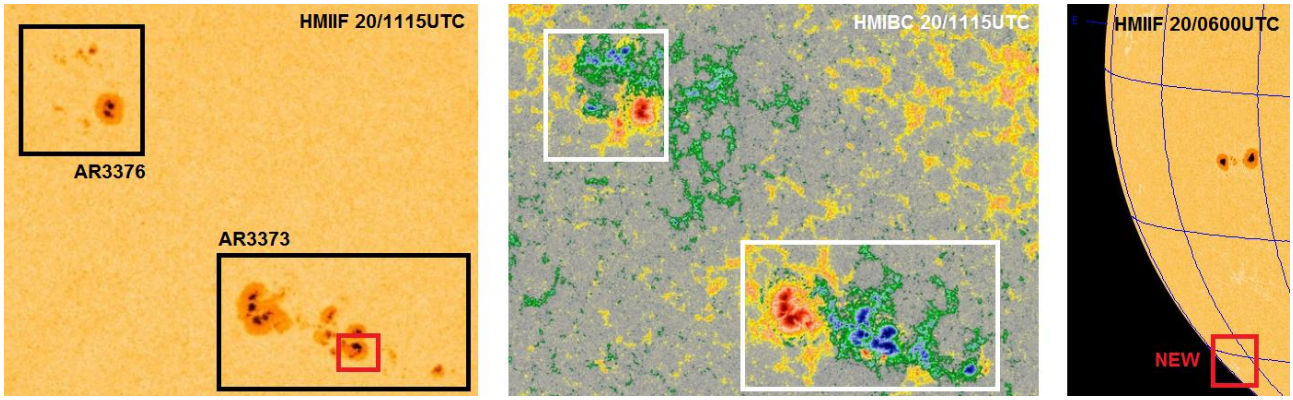
Partly as a result of AR3363's departure, the X-ray forecast is slightly lower confidence and in a state of flux at present, as although the disc nominally supports further M-class activity, this does seem relatively less likely with the departure of Ex-AR3363. All considered, the tentatively identified new lower level of risk may now again rise day-on-day with progressive arrivals in the four day period.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	50	50	60	60
Very Active	R3 to R5 X Class	No	5	5	10	10

Figure 3: HMIIF and HMIBC of sunspot regions on interest, including the reversed and north-south aligned AR3376; large, complex and delta containing AR3373 (delta boxed red); and lat-lon gridded HMIIF imagery of a high latitude arriving spot.



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Solar Radiation Storms - (High Energy Protons):

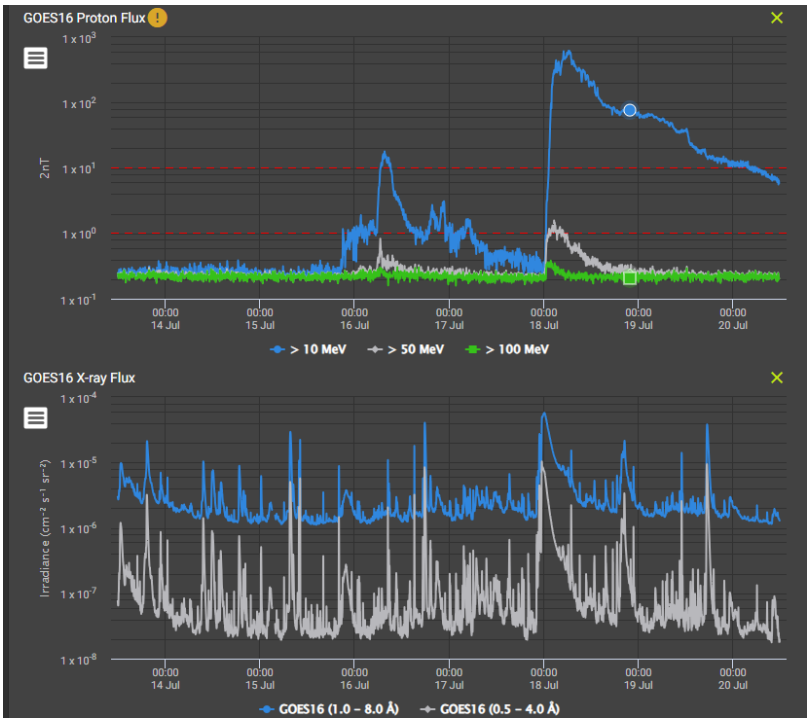
The high energy (greater than 10MeV) proton flux has recently crossed the S1 threshold on a downward trajectory, having earlier reached a peak of S2 and 620pfu at 18/0620UTC. The chances of further such occurrences are held higher than the raw disc probabilities - both for the presence of Ex-AR3363 over the limb, but also because of the high starting point for near-Earth proton flux, meaning relatively little further addition is needed for S1 at least.

As a final consideration, some of the largest and active regions on the current Earth facing disc, namely AR3373 and AR3376, transit across the western hemisphere over the coming days.

The risk of S1 or above therefore shows a gradual relaxing trend in the four days towards the current raw disc probability, perhaps reaching a steady state once again into the new UTC working week.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	Yes	50	30	20	15
Very Active	**≥ S3 ***	No	5	5	5	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: Past week in GOES16 high energy proton flux, showing numerous reactions to both near- and far-sided activity (i.e. not always tied to large front-sided X-ray flares and with both soft and hard spectra visible).



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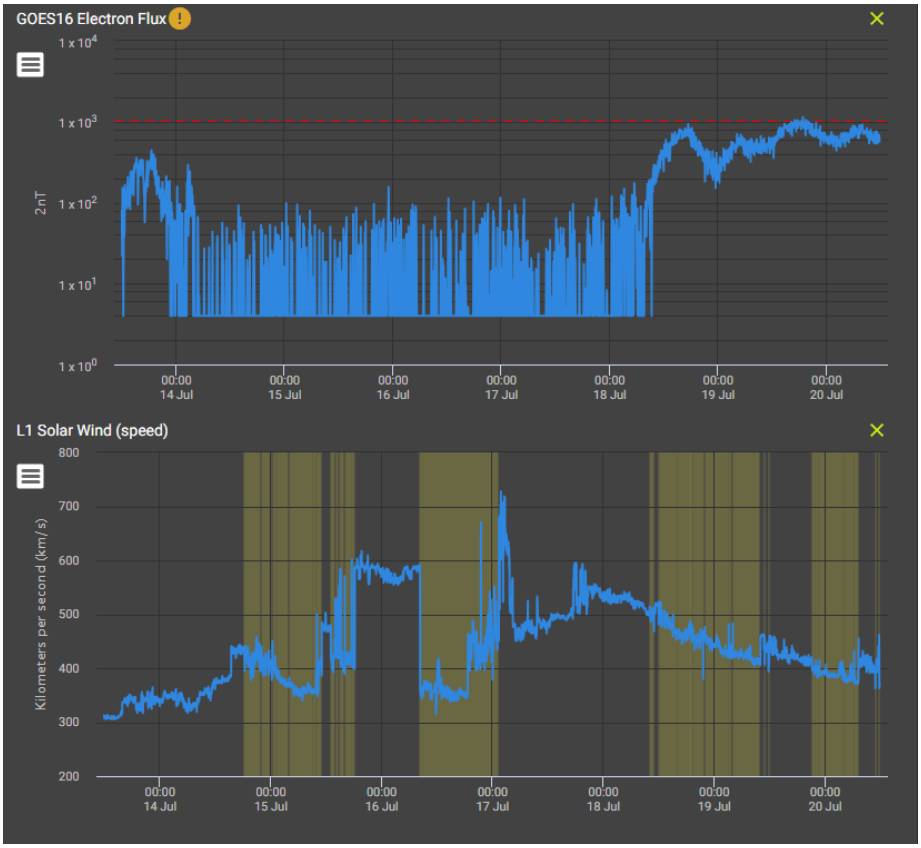
High Energy Electrons Event (≥ 2MeV):

High energy electron flux (greater than 2MeV) has been largely at Moderate levels in the past 24 hours, having apparently reached a steady state in the wake of the CME that arrived on 16 July. The forecast from here carries low confidence owing to CME influence, however there is a Chance of an eventual increase once initial geomagnetic activity subsides. This is perhaps less likely than shown in recent guidance, given the manifestly late CME due in the current UTC day which is therefore slower or of more glancing incidence.

As stated above, the relative lack of predictable fast wind streams and the dominance of a transient-peppered forecast means that REFM is not considered good guidance, or at least it has an incorrect rationale for a similar result.

GEO Electron Environment	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ $1x10^8$	No	10	5	40	50
Very Active	≥ 2 MeV ≥ $1x10^9$	No	1	1	5	5

Figure 5: Past week in GOES16 high energy electrons, showing current (probable) steady-state moderate flux in response to the 16 July CME arrival and ensuing fast wind. The presence of up to two further CMEs in the forecast to end the current UTC working week renders REFM guidance moot.



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